DIN EN ISO 13680

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Einsprüche bis 2019-05-22
Vorgesehen als Ersatz für
DIN EN ISO 13680:2010-12

Entwurf

Erdöl- und Erdgasindustrie – Nahtlose Rohre aus korrosionsbeständigen Legierungen zur Verwendung als Futter- oder Steigrohre sowie Muffenvorrohre – Technische Lieferbedingungen (ISO/DIS 13680:2019); Englische Fassung prEN ISO 13680:2019, nur auf CD-ROM

Petroleum and natural gas industries – Corrosion-resistant alloy seamless tubular products for use as casing, tubing, coupling stock and accessory material – Technical delivery conditions (ISO/DIS 13680:2019); English version prEN ISO 13680:2019, only on CD-ROM

Industries du pétrole et du gaz naturel – Tubes sans soudure en acier allié résistant à la corrosion utilisés comme tubes de cuvelage, tubes de production et tubes-ébauches pour manchons – Conditions techniques de livraison (ISO/DIS 13680:2019); Version anglaise prEN ISO 13680:2019, seulement en CD-ROM

Anwendungswarnvermerk

Dieser Norm-Entwurf mit Erscheinungsdatum 2019-03-22 wird der Öffentlichkeit zur Prüfung und Stellungnahme vorgelegt.

Weil die beabsichtigte Norm von der vorliegenden Fassung abweichen kann, ist die Anwendung dieses Entwurfs besonders zu vereinbaren.

Stellungnahmen werden erbeten

- vorzugsweise online im Norm-Entwurfs-Portal von DIN unter www.din.de/go/entwuerfe bzw. für Norm-Entwürfe der DKE auch im Norm-Entwurfs-Portal der DKE unter www.entwuerfe.normenbibliothek.de, sofern dort wiedergegeben;
- oder als Datei per E-Mail an noeg@din.de möglichst in Form einer Tabelle. Die Vorlage dieser Tabelle kann im Internet unter www.din.de/go/stellungnahmen-norm-entwuerfe oder für Stellungnahmen zu Norm-Entwürfen der DKE unter www.dke.de/stellungnahme abgerufen werden;
- oder in Papierform an den DIN-Normenausschuss Erdöl- und Erdgasgewinnung (NÖG), 10772 Berlin, Saatwinkler Damm 42/43, 13627 Berlin.

Die Empfänger dieses Norm-Entwurfs werden gebeten, mit ihren Kommentaren jegliche relevanten Patentrechte, die sie kennen, mitzuteilen und unterstützende Dokumentationen zur Verfügung zu stellen.

Gesamtumfang 156 Seiten

DIN-Normenausschuss Erdöl- und Erdgasgewinnung (NÖG)

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Nationales Vorwort

Dieses Dokument (prEN ISO 13680:2019) wurde vom Technischen Komitee ISO/TC 67 „Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries“ in Zusammenarbeit mit dem Technischen Komitee CEN/TC 12 „Materialien, Ausrüstungen und Offshore-Bauwerke für die Erdöl-, petrochemische und Erdgasindustrie“ erarbeitet, dessen Sekretariat vom NEN (Niederlande) gehalten wird.

Das zuständige deutsche Normungsgremium ist der Arbeitskreis NA 109-00-01-05 AK „Futter-, Steig- und Bohrrohre — Spiegelausschuss zu ISO/TC 67/SC 5“ im DIN-Normenausschuss Erdöl- und Erdgasgewinnung (NÖG).

Diese Europäische Norm enthält unter Berücksichtigung des DIN-Präsidialbeschlusses 1/2004 nur die englische Originalfassung der ISO Norm.

Diese Norm enthält neben den gesetzlichen Einheiten auch die Einheiten „°F“, „ft“, „ft · lb“, „in (inch)“, „ksi“, „lb (pound)“, „lb/ft²“, „ppm“ und „psi (psig)“, die in Deutschland nicht zugelassen sind. Es wird ausdrücklich darauf hingewiesen, dass die Anwendung dieser Einheiten im nationalen amtlichen und geschäftlichen Verkehr aufgrund des Gesetzes über Einheiten im Messwesen nicht zulässig ist. Die Angabe dieser Einheiten dient lediglich als Hilfe im amtlichen und geschäftlichen Verkehr (z. B. bei Einfuhr und Ausfuhr) mit solchen Staaten, die diese Einheiten anwenden.

Umrechnung:

Nicht-SI-Einheit	**SI-Einheit**	**Umrechnung**	
°F	°C	°C	= (5/9) (°F-32)
ft	m	1 ft	= 0,304 8 m
ft · lb	Nm	1 ft · lb	= 1,35 Nm
in (inch)	mm	1 inch	= 25,4 mm
ksi	MPa	1 ksi	= 6,894 757 MPa
lb (pound)	kg	1 lb	= 0,453 592 37 kg
lb/ft²	kg/m²	1 lb/ft²	= 4,882 kg/m²
ppm	mg/kg	1 ppm	= 1 mg/kg
psi (psig)	kPa	1 psi	= 6,894 757 kPa

Für die in diesem Dokument zitierten Internationalen Normen wird im Folgenden auf die entsprechenden Deutschen Normen hingewiesen:

ISO 148-1	siehe	DIN EN ISO 148-1
ISO 377	siehe	DIN EN ISO 377
ISO 525	siehe	DIN ISO 525
ISO 643	siehe	DIN EN ISO 643
ISO 3452-1	siehe	DIN EN ISO 3452-1

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ISO 4287	siehe	DIN EN ISO 4287
ISO 4885	siehe	DIN EN ISO 4885
ISO 6506-1	siehe	DIN EN ISO 6506-1
ISO 6508-1	siehe	DIN EN ISO 6508-1
ISO 6508-2	siehe	DIN EN ISO 6508-2
ISO 6892-1	siehe	DIN EN ISO 6892-1
ISO 6892-2	siehe	DIN EN ISO 6892-2
ISO 8501-1	siehe	DIN EN ISO 8501-1
ISO 9712	siehe	DIN EN ISO 9712
ISO 9934-1	siehe	DIN EN ISO 9934-1
ISO 10423	siehe	DIN EN ISO 10423
ISO 10893-1	siehe	DIN EN ISO 10893-1
ISO 10893-2	siehe	DIN EN ISO 10893-2
ISO 10893-3	siehe	DIN EN ISO 10893-3
ISO 10893-4	siehe	DIN EN ISO 10893-4
ISO 10893-5	siehe	DIN EN ISO 10893-5
ISO 10893-8	siehe	DIN EN ISO 10893-8
ISO 10893-10	siehe	DIN EN ISO 10893-10
ISO 10893-12	siehe	DIN EN ISO 10893-12
ISO 14284	siehe	DIN EN ISO 14284
ISO 15156 (all parts)	siehe	DIN EN ISO 15156 (alle Teile)
ISO 80000-1	siehe	DIN EN ISO 80000-1

Änderungen

Gegenüber DIN EN ISO 13680:2010-12 wurden folgende Änderungen vorgenommen:

a) normative Verweisungen aktualisiert;

b) Literaturhinweise aktualisiert;

c) Überarbeitung der Begriffe, Abkürzungen und Symbole;

d) Abschnitt 6 „Manufacturing process“ überarbeitet;

e) Unterabschnitt 9.6 „Hardness test“ überarbeitet;

f) Unterabschnitt 9.8 „Microstructural examination“ überarbeitet;

g) Unterabschnitt 9.17 „Positive material identification“ ergänzt;

h) Abschnitt 11 „Marking“ überarbeitet;

i) Anhang A, Anhang F und Anhang G überarbeitet;

j) Anhang B und Anhang C erweitert;

k) Anhang H und Anhang I ergänzt;

l) redaktionelle Überarbeitung.

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Nationaler Anhang NA
(informativ)

Begriffe

3 Begriffe

Die Benummerung der folgenden Begriffe ist identisch mit der Benummerung in der englischen Fassung.

3.1.1
Ausgangsmaterial für Zubehörteile
nahtlose Futter- oder Steigrohre oder nahtlose dickwandige Rohre oder stabförmige Halbzeuge oder Warmschmiedeteile, die für die Herstellung von Zubehörteilen verwendet werden

3.1.2
stabförmiges Halbzeug
Stab
Material mit einem gleichmäßigen Vollquerschnitt über dessen gesamte Länge

3.1.3
Futterrohr
Rohr, das zum Auskleiden der Bohrlochwände vorgesehen ist

3.1.4
kaltverfestigt
Werkstoffzustand, in dem die mechanischen Eigenschaften durch Kaltbearbeitung ohne nachfolgende Wärmebehandlung erreicht werden

Anmerkung 1 zum Begriff: Die Kaltbearbeitung ist eine plastische Formgebung des Werkstoffs bei einer Temperatur unter der Rekristallisationstemperatur, wodurch eine dauerhafte Kaltverfestigung auftritt.

Anmerkung 2 zum Begriff: Der prozentuale Anteil der Kaltverfestigung ist für jede Werkstoffsorte vom festgelegten Festigkeitsniveau abhängig, wie in Tabelle A.3 oder Tabelle C.3 für den kalt verfestigten Zustand gezeigt wird.

3.1.5
korrosionsbeständige Legierung
CRA
Legierung, deren Beständigkeit gegen allgemeine und örtliche Korrosion und/oder umgebungsbedingte Spannungsrissbildung in den Umgebungen vorgesehen ist, die korrosive Effekte auf unlegierte und niedrig legierte Stähle ausüben

3.1.6
Muffen-Rohling
Material ohne Gewinde, das zur Herstellung einer einzelnen Kupplung verwendet wird

3.1.7
Muffen-Vorrohr
nahtloses, dickwandiges Rohrprodukt, das zur Herstellung von Muffen-Rohlingen verwendet wird

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3.1.8
Fehler
Mangel in einem so ausreichenden Ausmaß, dass die Zurückweisung des Produkts auf Grundlage der in diesem Dokument festgelegten Kriterien gerechtfertigt ist

3.1.9
Schmelze
Werkstoff der gleichen Kategorie, der im selben Herstellungsprozess geschmolzen wird und in derselben zeitlichen Abfolge zu mehreren Blöcken oder in einem kontinuierlichen Strang vergossen wird

Anmerkung 1 zum Begriff: Im Falle einer umgeschmolzenen Legierung muss für jeden Block eine unterschiedliche Wärme berücksichtigt werden.

3.1.10
warmgefertigt
Werkstoffzustand, der erreicht wird, wenn eine bleibende Verformung von Metall bei einer Temperatur und Dehnrate durchgeführt wird, bei der gleichzeitig mit der Formgebung eine Rekristallisation stattfindet, wodurch eine bleibende Kaltverfestigung verhindert wird

3.1.11
Mangel (Fehlerhaftigkeit eines Produkts)
Unstetigkeitsstelle auf der Oberfläche oder in der Wand des Produkts, die durch Sichtprüfung oder zerstörungsfreie Prüfverfahren (NDE-Verfahren), wie in diesem Dokument festgelegt, nachgewiesen werden kann

3.1.12
Bezeichnung 1
dimensionslose Bezeichnung für die Nennweite oder den festgelegten Außendurchmesser, die bei der Rohrbestellung angewendet werden darf

3.1.13
Bezeichnung 2
dimensionslose Bezeichnung für die längenbezogene Masse, die bei der Rohrbestellung angewendet werden darf

Anmerkung 1 zum Begriff: Die längenbezogene Masse wird mitunter als „Masse je Längeneinheit“ bezeichnet.

3.1.14
linienförmiger Mangel
Mangel, beispielsweise Überwalzungen, Überlappungen, Risse, Vertiefungen, Einschnitte und Fugen

3.1.15
Hersteller
Firma, Unternehmen oder Gesellschaft mit Einrichtungen zur Herstellung nahtloser Rohre, die als Futterrohre, Steigrohre, Muffen-Vorrohre oder Ausgangsmaterial für Zubehörteile zu verwenden sind

3.1.16
Rohr
Futterrohre, Steigrohre und kurze Verbindungsrohre als Gruppe von Rohren mit glatten Enden

3.1.17
Produkt
rohrförmiges Produkt
Rohr und/oder Muffen-Vorrohr und/oder Ausgangsmaterial für Zubehörteile, entweder einzeln oder, wenn zutreffend, gemeinsam

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3.1.18
kurzes Verbindungsrohr
Futter oder Steigrohr mit einer geringeren Länge als für den Bereich 1

3.1.19
Abschreckhärten
Abschrecken
Wärmebehandlung, die eine Austenitisierung mit nachfolgender Abkühlung unter Bedingungen erfordert, unter denen sich Austenit in Martensit umwandeln kann

Anmerkung 1 zum Begriff: Auf das Abschreckhärten folgt häufig ein Anlassen.

Anmerkung 2 zum Begriff: Übernommen aus ISO 4885.

3.1.20
Lösungsglühen
Wärmebehandlung, die ein Erwärmen auf eine geeignete Temperatur und ein Halten dieser Temperatur für eine so ausreichende Dauer erfordert, dass ein Bestandteil oder mehrere Bestandteile in eine feste Lösung übergehen, mit nachfolgend so raschem Abkühlen, dass die gelösten Bestandteile den Zustand der festen Lösung beibehalten

Anmerkung 1 zum Begriff: Lösungsglühen kann vor dem Warmumformen oder als getrennter Vorgang durchgeführt werden.

3.1.21
Anlassen
Wärmebehandlung, die ein ein- oder mehrmaliges Erwärmen auf eine festgelegte Temperatur unter der unteren kritischen Temperatur und ein Halten dieser Temperatur erfordert

Anmerkung 1 zum Begriff: Das Anlassen wird häufig nach dem Abschreckhärten durchgeführt.

Anmerkung 2 zum Begriff: Übernommen aus ISO 4885.

3.1.22
Prüflos
Los
<für Produkte außer Stäbe oder Bohrstangen> Einheit, gebildet aus Produkten aus derselben Schmelze, mit den gleichen festgelegten Außendurchmessern und Wanddicken, aus identischen Werkstoffsorten nach dem gleichen Herstellungsprozess, unter gleichen Bedingungen bei der abschließenden Wärmebehandlung, mit den gleichen Prozessanlagen und -parametern für alle Wärmebehandlungsstufen, nacheinander für Durchlauföfen oder gleichzeitig für Chargenöfen und mit den gleichen Kennwerten für die Kaltverfestigung (falls zutreffend) hergestellt und in dem Längenbereich, der in Tabelle A.16 und Tabelle C.16 festgelegt ist

Anmerkung 1 zum Begriff: Die maximale Anzahl von Produkten in einem Prüflos wird in Tabelle A.21 und Tabelle C.21 angegeben.

3.1.23
Prüflos
Los
<für Stäbe oder Bohrstangen> Einheit, gebildet aus Produkten aus derselben Schmelze, mit den gleichen festgelegten Außendurchmessern, der gleichen Wanddicke (falls zutreffend), aus identischen Werkstoffsorten, mit den gleichen Prozessanlagen und -parametern für alle Wärmebehandlungsstufen, nacheinander für Durchlauföfen oder gleichzeitig für Chargenöfen hergestellt

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3.1.24
Steigrohr
Rohr, das in einer Bohrung angeordnet wird und zum Fördern des Erdöls/Erdgases oder zum Einspülen der Bohrspülung vorgesehen ist

3.1 Abkürzungen

AH	Ausgehärtet
AOD	Argon-Sauerstoff-Frischen (Argon-Sauerstoff-Entkohlung)
CH	Kaltverfestigt
EDI	Elektronischer Datenaustausch
EDX	Energiedispersive Röntgenfluoreszenzspektrometrie
EMI	Prüfung auf elektromagnetische Störfestigkeit
ESR	Umschmelzen von Elektroschlacke
HBW	Brinell-Härte während des Prüfens mit einer Wolframcarbid-Kugel
HF	Warmgefertigt
HRC	Rockwell-Härte, C-Skale
ID	Innendurchmesser
L+T	Längs und quer
MPQT	Prüfungen für die Qualifizierung des Herstellverfahrens
MT	Magnetpulverprüfung
NA	Nicht zutreffend; nicht anwendbar
NDE	Zerstörungsfreie Prüfung
OD	Außendurchmesser
PMI	Positive Materialidentifizierung
PREN	PREN-Index als Maß für die Korrosionsfestigkeit
PSL	Stufe der Produktspezifikation
QT	Abgeschreckt und angelassen
QTC	Qualifizierendes Probestück
SA	Lösungsgelüht
SI	Internationales Einheitensystem

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UNS UNS-Nummer

USC Angloamerikanisches Maßsystem

UT Ultraschallprüfung

VAD Vakuumlichtbogenentgasung

VAR Vakuumlichtbogenumschmelzen

VIM Vakuuminduktionsschmelzen

VOD Vakuum-Sauerstoff-Frischen (Vakuum-Sauerstoff-Entkohlung)

3.2 Symbole

A Querschnitt der Zugprobe, in Quadratmillimeter (Quadratzoll), berechnet auf Grundlage des festgelegten Außendurchmessers oder der Nennbreite der Probe und der festgelegten Wanddicke, gerundet auf die nächsten 10 mm^2 (0,01 in^2), oder 490 mm^2 (0,75 in^2), wobei jeweils der kleinere Wert anzuwenden ist

C_v Geforderte Schlagenergie nach Charpy an Proben mit V-Kerb, in Joule (Foot-Pound)

D Außendurchmesser des Produkts, in Millimeter (Zoll)

d Innendurchmesser des Produkts, in Millimeter (Zoll)

e Kleinste Dehnung für eine Messlänge von 50,8 mm (2,0 in) für Streifenproben oder von $4D$ für Rundzugproben, in Prozent

f Faktor (für die hydrostatische Prüfung): 0,8 (0.8) für alle Sorten und Größen

m Masse

p Hydrostatischer Prüfdruck, in Megapascal (1 000 Pound je Quadratzoll)

Ra mittlere Oberflächenrauigkeit wie in ISO 4287 festgelegt

R_m Zugfestigkeit, in Megapascal (1 000 Pound je Quadratzoll)

$R_{p0,2}$ Streckgrenze (bei 0,2 % nichtproportionaler Dehnung), in Megapascal (1 000 Pound je Quadratzoll)

t Wanddicke des Produkts, in Millimeter (Zoll)

w_x Prozentualer Massenanteil des Elements x

$Y_{S,min}$ Kleinste festgelegte Streckgrenze, in Megapascal (1 000 Pound je Quadratzoll)

$Y_{S,max}$ Größte festgelegte Streckgrenze, in Megapascal (1 000 Pound je Quadratzoll)

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Nationaler Anhang NB
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Literaturhinweise

DIN EN ISO 148-1, *Metallische Werkstoffe —Kerbschlagbiegeversuch nach Charpy — Teil 1: Prüfverfahren*

DIN EN ISO 377, *Stahl und Stahlerzeugnisse — Lage und Vorbereitung von Probenabschnitten und Proben für mechanische Prüfungen*

DIN ISO 525, *Schleifkörper aus gebundenem Schleifmittel — Allgemeine Anforderungen*

DIN EN ISO 643, *Stahl - Mikrophotographische Bestimmung der erkennbaren Korngröße*

DIN EN ISO 3452-1, *Zerstörungsfreie Prüfung — Eindringprüfung — Teil 1: Allgemeine Grundlagen*

DIN EN ISO 4287, *Geometrische Produktspezifikation (GPS) — Oberflächenbeschaffenheit: Tastschnittverfahren — Benennungen, Definitionen und Kenngrößen der Oberflächenbeschaffenheit*

DIN EN ISO 4885, *Eisenwerkstoffe — Wärmebehandlung — Begriffe*

DIN EN ISO 6506-1, *Metallische Werkstoffe — Härteprüfung nach Brinell — Teil 1: Prüfverfahren*

DIN EN ISO 6508-1, *Metallische Werkstoffe — Härteprüfung nach Rockwell — Teil 1: Prüfverfahren*

DIN EN ISO 6508-2, *Metallische Werkstoffe — Härteprüfung nach Rockwell — Teil 2: Überprüfung und Kalibrierung der Prüfmaschinen und Eindringkörper*

DIN EN ISO 6892-1, *Metallische Werkstoffe — Zugversuch — Teil 1: Prüfverfahren bei Raumtemperatur*

DIN EN ISO 6892-2, *Metallische Werkstoffe — Zugversuch — Teil 2: Prüfverfahren bei erhöhter Temperatur*

DIN EN ISO 8501-1, *Vorbereitung von Stahloberflächen vor dem Auftragen von Beschichtungsstoffen — Visuelle Beurteilung der Oberflächenreinheit — Teil 1: Rostgrade und Oberflächenvorbereitungsgrade von unbeschichteten Stahloberflächen und Stahloberflächen nach ganzflächigem Entfernen vorhandener Beschichtungen*

DIN EN ISO 9712, *Zerstörungsfreie Prüfung — Qualifizierung und Zertifizierung von Personal der zerstörungsfreien Prüfung*

DIN EN ISO 9934-1, *Zerstörungsfreie Prüfung — Magnetpulverprüfung — Teil 1: Allgemeine Grundlagen*

DIN EN ISO 10423, *Erdöl- und Erdgasindustrie — Bohr- und Förderausrüstung — Bohrlochkopf- und Eruptionskreuz-Ausrüstung*

DIN EN ISO 10893-1, *Zerstörungsfreie Prüfung von Stahlrohren — Teil 1: Automatisierte elektromagnetische Prüfung nahtloser und geschweißter (ausgenommen unterpulvergeschweißter) Stahlrohre zum Nachweis der Dichtheit*

DIN EN ISO 10893-2, *Zerstörungsfreie Prüfung von Stahlrohren — Teil 2: Automatisierte Wirbelstromprüfung nahtloser und geschweißter (ausgenommen unterpulvergeschweißter) Stahlrohre zum Nachweis von Unvollkommenheiten*

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DIN EN ISO 10893-3, *Zerstörungsfreie Prüfung von Stahlrohren — Teil 3: Automatisierte Streuflussprüfung nahtloser und geschweißter (ausgenommen unterpulvergeschweißter) ferromagnetischer Stahlrohre über den gesamten Rohrumfang zum Nachweis von Unvollkommenheiten in Längs- und/oder Querrichtung*

DIN EN ISO 10893-4, *Zerstörungsfreie Prüfung von Stahlrohren — Teil 4: Eindringprüfung nahtloser und geschweißter Stahlrohre zum Nachweis von Oberflächenunvollkommenheiten*

DIN EN ISO 10893-5, *Zerstörungsfreie Prüfung von Stahlrohren — Teil 5: Magnetpulverprüfung nahtloser* und *geschweißter ferromagnetischer Stahlrohre zum Nachweis von Oberflächenunvollkommenheiten*

DIN EN ISO 10893-8, *Zerstörungsfreie Prüfung von Stahlrohren — Teil 8: Automatisierte Ultraschallprüfung nahtloser und geschweißter Stahlrohre zum Nachweis von Dopplungen*

DIN EN ISO 10893-10, *Zerstörungsfreie Prüfung von Stahlrohren — Teil 10: Automatisierte Ultraschallprüfung nahtloser und geschweißter (ausgenommen unterpulvergeschweißter) Stahlrohre über den gesamten Rohrumfang zum Nachweis von Unvollkommenheiten in Längs- und/oder Querrichtung*

DIN EN ISO 10893-12, *Zerstörungsfreie Prüfung von Stahlrohren — Teil 12: Automatisierte Ultraschall-Wanddickenprüfung nahtloser und geschweißter (ausgenommen unterpulvergeschweißter) Stahlrohre über den gesamten Rohrumfang*

DIN EN ISO 14284, *Stahl und Eisen — Entnahme und Vorbereitung von Proben für die Bestimmung der chemischen Zusammensetzung*

DIN EN ISO 15156 (alle Teile), *Erdöl- und Erdgasindustrie — Werkstoffe für den Einsatz in H 2 S-haltiger Umgebung bei der Öl- und Gasgewinnung*

DIN EN ISO 80000-1, *Größen und Einheiten — Teil 1: Allgemeines*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

The committee responsible for this document is Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 5, *Casing, tubing and drill pipe*.

This fourth edition cancels and replaces the third edition (ISO 13680:2010), with introduction of substantial changes. The main changes compared to the previous edition are as follows:

— change of title and scope for introduction of accessory material and group 5;

— deletion of former Annex F;

— introduction of new Annex F and associated Tables A.29, A.30, A.31, A.32, C.29, C.30, C.31 and C.32;

— introduction of new Annex H and Annex I;

— changes to warning statement; Clauses 1, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 13; Tables A.1, A.2, A.3, A.15, A.16, A.17, A.19, A.20, A.21, A.22, A.27, A.28, C.1, C.2, C.3, C.15, C.16, C.17, C.19, C.20, C.21, C.22, C.27 and C.28; Figures B.4 and B.8; Annex E; Annex G.

It is the intent of ISO/TC 67 that the third and fourth editions of ISO 13680 can both be applicable, at the option of the purchaser, for a period of twelve months from the first day of the calendar quarter immediately following the date of publication of this fourth edition, after which period the third edition will no longer be applicable.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

It is necessary that users of this document are aware that further or differing requirements can be needed for individual applications. This document is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This can be particularly applicable where there is innovative or developing technology. Where an alternative is offered, it is the responsibility of the vendor to identify any variations from this document and provide details.

In this document, the following verbal forms are used:

a) “shall” indicates a requirement;

b) “should” indicates a recommendation;

c) “may” indicates a permission;

d) “can” indicates a possibility or a capability.

Information marked as “NOTE” is for guidance in understanding or clarifying the associated requirement. “Notes to entry” used in Clause 3 provide additional information that supplements the terminological data and can contain provisions relating to the use of a term.

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Petroleum and natural gas industries — Corrosion-resistant alloy seamless tubular products for use as casing, tubing, coupling stock and accessory material — Technical delivery conditions

WARNING — It is the purchaser's responsibility to specify the product specification level (PSL), corrosion-resistant alloy (CRA) group, category, grade, delivery conditions and any other requirements in addition to those specified herewith to ensure that the product is adequate for the intended service environment. ISO 15156 (all parts) should be considered when making specific requirements for H_2S-containing environment; see Annex G. Other variables which can contribute to hydrogen embrittlement should be considered. There are other sources of hydrogen besides H_2S containing environments, which are not addressed by ISO 15156 (all parts).

NOTE For the purpose of this document, NACE MR0175 is equivalent to ISO 15156 (all parts).

1 Scope

This document specifies the technical delivery conditions for corrosion-resistant alloy seamless tubular products for casing, tubing, coupling stock and accessory material for two product specification levels:

— PSL-1, which is the basis of this document;

— PSL-2, which provides additional requirements for a product that is intended to be both corrosion resistant and cracking resistant for the environments and qualification method specified in ISO 15156 (all parts) and Annex G of this document.

At the option of the manufacturer, PSL-2 products can be provided in lieu of PSL-1.

NOTE 1 The corrosion-resistant alloys included in this document are special alloys in accordance with ISO 4948-1 and ISO 4948-2.

NOTE 2 For the purpose of this document, NACE MR0175 is equivalent to ISO 15156 (all parts).

This document is applicable to the following five groups of products:

a) group 1, which is composed of stainless alloys with a martensitic or martensitic/ferritic structure;

b) group 2, which is composed of stainless alloys with a ferritic-austenitic structure, such as duplex and super-duplex stainless alloy;

c) group 3, which is composed of stainless alloys with an austenitic structure (iron base);

d) group 4, which is composed of nickel-based alloys with an austenitic structure (nickel base);

e) group 5, which is composed of bar only (Annex F) in age-hardened (AH) nickel-based alloys with austenitic structure.

This document contains no provisions relating to the connection of individual lengths of pipe.

This document contains provisions relating to marking of tubing and casing after threading.

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NOTE 3 The connection or joining method can influence the corrosion performance of the materials specified in this document.

NOTE 4 It is necessary to recognize that not all PSL-1 categories and grades can be made cracking resistant in accordance with ISO 15156 (all parts) and are, therefore, not included in PSL-2.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 148-1, *Metallic materials — Charpy pendulum impact test — Part 1: Test method*

ISO 377, *Steel and steel products — Location and preparation of samples and test pieces for mechanical testing*

ISO 404, *Steel and steel products — General technical delivery requirements*

ISO 525, *Bonded abrasive products — General requirements*

ISO 643, *Steels– Micrographic determination of the apparent grain size*

ISO 3452-1, *Non-destructive testing — Penetrant testing — Part 1: General principles*

ISO 4287, *Geometrical Product Specifications (GPS) – Surface texture: Profile method – Terms, definitions and surface texture parameters*

ISO 4885, *Ferrous products — Heat treatments — Vocabulary*

ISO 4948-1, *Steels — Classification — Part 1: Classification of steels into unalloyed and alloy steels based on chemical composition*

ISO 4948-2, *Steels — Classification — Part 2: Classification of unalloyed and alloy steels according to main quality classes and main property or application characteristics*

ISO 6506-1, *Metallic materials — Brinell hardness test — Part 1: Test method*

ISO 6508-1, *Metallic materials — Rockwell hardness test — Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T)*

ISO 6508-2, *Metallic materials — Rockwell hardness test — Part 2: Verification and calibration of testing machines (scales A, B, C, D, E, F, G, H, K, N, T)*

ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

ISO 6892-2, *Metallic materials — Tensile testing — Part 2: Method of test at elevated temperature*

ISO 6929, *Steel products — Definitions and classification*

ISO 8501-1, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings*

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ISO 9712, *Non-destructive testing — Qualification and certification of personnel*

ISO 9934-1, *Non-destructive testing — Magnetic particle testing — Part 1: General principles*

ISO 10423, *Petroleum and natural gas industries — Drilling and production equipment — Wellhead and christmas tree equipment*

ISO 10474, *Steel and steel products — Inspection documents*

ISO 10893-1, *Non-destructive testing of steel tubes — Part 1: Automated electromagnetic testing of seamless and welded (except submerged arc-welded) steel tubes for the verification of hydraulic leaktightness*

ISO 10893-2, *Non-destructive testing of steel tubes — Part 2: Automated eddy current testing of seamless and welded (except submerged arc-welded) steel tubes for the detection of imperfections*

ISO 10893-3, *Non-destructive testing of steel tubes — Part 3: Automated full peripheral flux leakage testing of seamless and welded (except submerged arc-welded) ferromagnetic steel tubes for the detection of longitudinal and/or transverse imperfections*

ISO 10893-4, *Non-destructive testing of steel tubes — Part 4: Liquid penetrant inspection of seamless and welded steel tubes for the detection of surface imperfections*

ISO 10893-5, *Non-destructive testing of steel tubes — Part 5: Magnetic particle inspection of seamless and welded ferromagnetic steel tubes for the detection of surface imperfections*

ISO 10893-8, *Non-destructive testing of steel tubes — Part 8: Automated ultrasonic testing of seamless and welded steel tubes for the detection of laminar imperfections*

ISO 10893-10, *Non-destructive testing of steel tubes — Part 10: Automated full peripheral ultrasonic testing of seamless and welded (except submerged arc-welded) steel tubes for the detection of longitudinal and/or transverse imperfections*

ISO 10893-12, *Non-destructive testing of steel tubes — Part 12: Automated full peripheral ultrasonic thickness testing of seamless and welded (except submerged arc-welded) steel tubes*

ISO 11484, *Steel products — Employer's qualification system for non-destructive testing (NDT) personnel*

ISO 14284, *Steel and iron — Sampling and preparation of samples for the determination of chemical composition*

ISO 15156 (all parts), *Petroleum and natural gas industries — Materials for use in H_2S-containing environments in oil and gas production*

ISO 80000-1, *Quantities and units — Part 1: General*

API RP 578, *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*

API Spec 6A, *Specification for Wellhead and Christmas Tree Equipment*

API Standard 6ACRA, *Age-hardened Nickel-based Alloys for Oil and Gas Drilling and Production Equipment*

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ASNT SNT-TC-1A, *Recommended Practice — Non-Destructive Testing*

ASTM A370, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*

ASTM A604/A604M, *Standard Practice for Macroetch Testing of Consumable Electrode Remelted Steel Bars and Billets*

ASTM A941, *Standard Terminology Relating to Steel, Stainless Steel, Related Alloys and Ferroalloys*

ASTM E10, *Standard Test Method for Brinell Hardness of Metallic Materials*

ASTM E18, *Standard Test Methods for Rockwell Hardness of Metallic Materials*

ASTM E21, *Standard Test Methods for Elevated Temperature Tension Tests of Metallic Materials*

ASTM E23, *Standard Test Methods for Notched Bar Impact Testing of Metallic Materials*

ASTM E29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

ASTM E45, *Standard Test Methods for Determining the Inclusion Content of Steel*

ASTM E110, *Standard Test Method for Rockwell and Brinell Hardness of Metallic Materials by Portable Hardness Testers*

ASTM E112, *Standard Test Methods for determining the average Grain Size*

ASTM E165, *Standard Practice for Liquid Penetrant Examination for General Industry*

ASTM E213, *Standard Practice for Ultrasonic Testing of Metal Pipe and Tubing*

ASTM E309, *Standard Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation*

ASTM E340, *Standard Test Method for Macroetching Metals and Alloys*

ASTM E381, *Standard Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings*

ASTM E562, *Standard Test Method for Determining Volume Fraction by Systematic Manual Point Count*

ASTM E570, *Standard Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products*

ASTM E709, *Standard Guide for Magnetic Particle Testing*

ASTM E1245, *Standard Practice for Determining the Inclusion or Second-Phase Constituent Content of Metals by Automatic Image Analysis*

ASTM E1476, *Standard Guide for Metals Identification, Grade Verification, and Sorting*

ASTM G48, *Standard Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution*

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3 Terms and definitions, abbreviated terms, and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 377, ISO 404, ISO 4885, ISO 4948-1, ISO 4948-2, ISO 6929, ISO 10474, ASTM A941 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1.1
accessory material
seamless casing or tubing or seamless thick-walled tube or bar stock or hot forging used for the manufacture of accessories

3.1.2
bar stock
bar
material with a solid uniform cross-section along its whole length

3.1.3
casing
pipe intended to line the walls of a drilled well

3.1.4
cold-hardened
material condition where the mechanical properties are obtained by a cold finishing process not followed by heat treatment

Note 1 to entry: Cold finishing is a plastic deformation of material at a temperature below the recrystallization temperature such that permanent strain hardening occurs.

Note 2 to entry: The percentage of cold hardening depends on the specified strength level for each material grade, as shown in Table A.3 or Table C.3 for the cold-hardened condition.

3.1.5
corrosion-resistant alloy
CRA
alloy intended to be resistant to general and localized corrosion and/or environmental cracking in environments that are corrosive to carbon and low-alloy steels

3.1.6
coupling blank
unthreaded material used to produce an individual coupling

3.1.7
coupling stock
seamless thick-wall tubular product used for the manufacture of coupling blanks

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3.1.8
defect
imperfection having sufficient magnitude to warrant rejection of the product based on the criteria defined in this document

3.1.9
heat
material of the same category melted in the same manufacturing process at the same time sequence poured into multiple ingots or continuous strand cast

Note 1 to entry: In case of a remelted alloy, each ingot shall be considered a different heat.

3.1.10
hot-finished
HF
material condition obtained by deforming metal plastically at such a temperature and strain rate that recrystallization takes place simultaneously with the deformation, thus preventing permanent strain hardening

3.1.11
imperfection
discontinuity on the product surface or in the product wall that can be detected by visual inspection or non-destructive examination (NDE) method outlined in this document

3.1.12
label 1
dimensionless designation for the size or specified outside diameter that may be used when ordering pipe

3.1.13
label 2
dimensionless designation for the linear density that may be used when ordering pipe

Note 1 to entry: Linear density is sometimes designated by the deprecated term “mass per unit length”.

3.1.14
linear imperfection
imperfection including, but not limited to, seams, laps, cracks, plug scores, cuts and gouges

3.1.15
manufacturer
firm, company or corporation that operates facilities for making seamless pipes for casing, tubing, coupling stock or accessory material

3.1.16
pipe
plain end casing, tubing and pup joint as group

3.1.17
product
tubular product
pipe and/or coupling stock and/or accessory material, either individually or collectively, as applicable

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3.1.18
pup joint
casing or tubing shorter than range 1

3.1.19
quench hardening
quenching
heat treatment requiring austenitization followed by cooling, under conditions such that austenite transforms into martensite

Note 1 to entry: Quench hardening is often followed by tempering.

Note 2 to entry: Adapted from ISO 4885.

3.1.20
solution annealing
heat treatment requiring heating to a suitable temperature, holding at that temperature long enough to cause one or more constituents to enter into solid solution, then cooling rapidly enough to hold such constituents in solution

Note 1 to entry: Solution annealing can be performed prior to hot forming or as a separate operation.

3.1.21
tempering
heat treatment requiring heating, one or more times, to a specific temperature below the lower critical temperature and holding at that temperature

Note 1 to entry: Tempering is often preceded by quench hardening.

Note 2 to entry: Adapted from ISO 4885.

3.1.22
test lot
lot
<for products other than bars or drilled bars> unit formed by products from the same heat, with the same specified outside diameter and wall thickness, the same grade, the same manufacturing process, the same final heat-treatment conditions, process facilities and parameters for all heat-treatment stages, processed sequentially for continuous furnaces or simultaneously for batch furnaces, the same cold hardening parameters (if applicable) and in the range length as defined in Table A.16 or Table C.16

Note 1 to entry: The maximum number of products in a test lot is found in Table A.21 or Table C.21.

3.1.23
test lot
lot
<for bars or drilled bars> unit formed by products from the same heat, with the same specified outside diameter, the same wall thickness (if applicable), the same grade, the same manufacturing process facilities and parameters for all heat-treatment stages, processed sequentially for continuous furnaces or simultaneously for batch furnaces

3.1.24
tubing
pipe placed in a well to produce or inject fluids

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3.2 Abbreviated terms

AH age-hardened

AOD argon oxygen decarburization

CH cold-hardened

EDI electronic data interchange

EDX energy dispersive X-ray spectrometry

EMI electromagnetic inspection

ESR electro-slag remelting

HBW Brinell hardness, when testing with a tungsten carbide ball

HF hot-finished

HRC Rockwell hardness C-scale

ID inside diameter

L + T longitudinal plus transverse

MPQT manufacturing procedure qualification test

MT magnetic-particle inspection

NA not applicable

NDE non-destructive examination

OD outside diameter

PMI positive material identification

PREN pitting-resistance equivalent number

PSL product specification level

QT quenched and tempered

QTC qualification test coupon

SA solution-annealed

SI International System of Units

UNS unified numbering system

USC United States customary system

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UT ultrasonic testing

VAD vacuum arc degassing

VAR vacuum arc remelting

VIM vacuum induction melting

VOD vacuum oxygen decarburization

3.3 Symbols

A cross-sectional area of the tensile test specimen, expressed in square millimetres (square inches), based on specified outside diameter or nominal specimen width and specified wall thickness, rounded to the nearest 10 mm^2 (0.01 in^2), or 490 mm^2 (0.75 in^2), whichever is smaller

C_v Charpy V-notch energy requirement, expressed in joules (foot pounds)

D outside diameter of the product, expressed in millimetres (inches)

d inside diameter of the product, expressed in millimetres (inches)

e minimum elongation in 50,8 mm (2.0 in) gauge length for strip specimens or in 4D for round bar specimens, expressed in percent

f factor (for hydrostatic test): 0,8 (0.8) for all grades and sizes

m mass

p hydrostatic test pressure, expressed in megapascals (thousand pounds per square inch)

Ra average surface roughness as defined in ISO 4287

R_m tensile strength, expressed in megapascals (thousand pounds per square inch)

$R_{p0,2}$ yield strength (0,2 % non-proportional elongation), expressed in megapascals (thousand pounds per square inch)

t wall thickness of the product, expressed in millimetres (inches)

w_x percent mass fraction of element x

$Y_{S,min}$ minimum specified yield strength, expressed in megapascals (thousand pounds per square inch)

$Y_{S,max}$ maximum specified yield strength, expressed in megapascals (thousand pounds per square inch)

4 Conformance

4.1 Dual normative references

In the interests of worldwide application of this document, ISO/TC 67 has decided, after detailed technical analysis, that certain of the normative documents listed in Clause 3 and prepared by ISO/TC 67 or another ISO Technical Committee are interchangeable in the context of the relevant requirement with the relevant document prepared by the American Petroleum Institute (API), the American Society for Testing and Materials (ASTM) or the American National Standards Institute (ANSI).

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These latter documents are cited in the running text following the ISO reference and preceded by “or”, for example “ISO XXXX or API YYYY”.

Application of an alternative normative document cited in this manner can lead to technical results that differ from the use of the preceding ISO reference. However, both results are acceptable and these documents are, thus, considered interchangeable in practice.

4.2 Units of measurement

In this document, data are expressed in both the International System (SI) of units and the United States Customary (USC) or other system of units. For a specific order item, it is intended that only one system of units be used, without combining data expressed in the other system.

Products manufactured to specifications expressed in either of these unit systems shall be considered equivalent and totally interchangeable. Consequently, compliance with the requirements of this document as expressed in one system provides compliance with requirements expressed in the other system.

For data expressed in SI units, a comma is used as the decimal separator and a space as the thousands separator.

For data expressed in USC units, a dot (on the line) is used as the decimal separator and a space as the thousands separator.

In the text, data in SI units are followed by data in USC or other units in parentheses.

Separate tables for data expressed in SI units and USC units are given in Annex A and Annex C, respectively.

Figures are contained in Annex B and express data in both SI and USC units.

5 Information to be supplied by the purchaser

5.1 The purchaser shall state the minimum information as given in Table 1, as applicable, in the enquiry and purchase agreement.

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Table 1 – Minimum information to be supplied by purchaser

Requirement		Reference
a)	Quantity of product	—
b)	Product designation: coupling stock or accessory material or plain end casing or tubing or upset product	For upset product, upset drawing and drift dimension shall be supplied by the purchaser
c)	Reference to this document	—
d)	Material category/grade	Table A.2 or Table C.2 and Table A.3 or Table C.3
e)	Label 1 and label 2 or specified outside diameter and specified wall thickness	Table A.15 or Table C.15 or as specified in purchase agreement per 8.1.2
f)	Coupling stock or accessory material dimensions, expressed in millimetres (inches)	As specified in purchase agreement
g)	Length range	8.2; Table A.16 or Table C.16 or as specified in purchase agreement
h)	Length for coupling stock or accessory material	As specified in purchase agreement
i)	Tolerances on outside diameter, wall thickness and mass of coupling stock or accessory material	8.3.1
j)	Inspection by the purchaser	Annex D
k)	Purchase requirements for bars intended for accessory material	F.2.1

5.2 The purchaser shall also state on the purchase agreement the requirements, where applicable, concerning the stipulations listed in Table 2. These stipulations are at the purchaser's option; if PSL-2 is not specified, the product will be supplied according to the requirements of PSL-1.

Table 2 – Additional requirements on purchase agreements

Requirement		Reference
a)	Cold swaging exceeding 3 % plastic strain without subsequent heat treatment	6.3.1
b)	End sizing by cold expansion	6.3.2
c)	MPQT program	6.7 and Annex H
d)	Chemical composition	7.1
e)	Difference between measured tensile strength and measured yield strength smaller than 34 MPa (5 ksi)	7.2
f)	Mechanical properties at elevated temperature	7.2
g)	Critical thickness for impact testing of coupling stock or accessory material	7.4.2
h)	Impact test temperature if lower than –10 °C (14 °F)	7.4.6
i)	Additional flattening tests for groups 3 and 4 materials	7.7
j)	Distance between plates when $D/t < 3$ or $D/t > 15$	7.7

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Requirement		Reference
k)	Corrosion testing	7.8
l)	Ferrite content for material 13-1-0	7.9.1
m)	Special surface condition	7.10
n)	Hydrostatic test	7.12 and 9.14
o)	Alternate drift mandrel	8.3.4
p)	Chromium depletion; minimum chromium content higher than 12,0 %	9.3.3
q)	Minimum signal-to-noise ratio lower than 3 to 1	9.16.9; 9.16.10
r)	Second outside surface NDE method for group 1 materials	9.16.9
s)	PMI for group 1	9.17
t)	Additional marking that is consistent with general marking	11.1
u)	Modification or elimination of colour code identification	11.2
v)	Colour code identification of couplings and accessories	11.4
w)	Surface protection for group 1 materials	12
x)	Surface protection	12.2
y)	Content of EDI-transmitted document	13.1
z)	For UNS N06975, $w_{Mo+W} \geq 6$ % mass fraction	Table A.28 or Table C.28
aa)	PSL-2	Annex G
bb)	Other test methods for MPQT	H.3.2
cc)	Purchase agreements for bars intended for accessory material	F.2.2

6 Manufacturing process

6.1 Melting practices

The alloys covered by this document shall be made by the basic oxygen process or the electric furnace process or blast furnace (group 1 only) or the VIM process, followed by further refining operations such as AOD, VOD, VAR, ESR, and VAD.

6.2 Product manufacturing process

Product manufacturing processes, starting material and heat-treatment or cold-hardened conditions are listed in Table A.1 or Table C.1.

Group 1 pipes and group 2 solution-annealed pipes shall be full-length heat-treated after any upsetting.

The manufacturer shall apply a process control plan that precludes the occurrence of phenomenon that can create surface effects (e.g. chromium depletion below 12,0 % mass fraction for groups 2, 3 and 4) on products where heat treatment is part of the manufacturing process, which can affect the corrosion resistance.

For group 2, the product shall be in the

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a) solution-annealed condition, or

b) solution-annealed and cold-hardened condition.

6.3 Pipe end sizing

6.3.1 Group 1 pipe may be end-sized such as swaging or expanding after final heat treatment for purposes of threading. When end sizing such as swaging or expanding exceeds 3 % plastic strain, group 1 pipe shall be either stress relieved at suitable temperature or full-length heat-treated in accordance with a documented procedure.

When the manufacturer has demonstrated and documented that the swaging process has not detrimentally affected the corrosion properties, by agreement between the purchaser and manufacturer, group 1 pipe may be cold swaged exceeding 3 % plastic strain without subsequent heat treatment.

If end sizing is performed before final full-length heat treatment, stress relief is not required.

6.3.2 For groups 2, 3 and 4 pipe, end sizing by cold swaging or cold expansion for purpose of threading is allowed. However, end sizing by cold expansion shall be only by agreement between purchaser and manufacturer.

NOTE 1 It is very difficult to stress relieve duplex stainless steels without causing sigma-phase formation.

NOTE 2 End sizing can detrimentally influence the corrosion performance of the materials specified in this document.

6.4 Straightening

For group 1, pipes shall be hot-rotary straightened, when necessary, after heat treatment, at 400 °C (750 °F) minimum at the end of rotary straightening, unless a higher minimum temperature is specified in the purchase agreement. If hot rotary straightening is not possible, the pipe may be cold straightened, provided it is then stress-relieved at 510 °C (950 °F) or higher. Light gag-press straightening shall be permitted, without subsequent stress relieving, if the induced maximum fibre strain is not exceeding the value validated by the manufacturer at the time of process validation (see 6.5).

For groups 2, 3, and 4, pipes shall be straightened, either using rotary straightening, gag-press straightening or a combination of both when necessary, utilizing parameters not exceeding the limits defined during validation of the process (see 6.5).

6.5 Process requiring validation

Those processes requiring validation are

— non-destructive examination (see 9.16.8);

— final heat treatment for group 1 (excluding stress relieving) and solution annealed group 2 materials;

— solution annealing immediately before final cold finishing steps for cold hardened material;

— stress relieving, if applicable;

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— cold straightening, if applicable, for group 1 (except when cold straightening is followed by stress relieving (see 6.4)) and solution annealed group 2 materials;

— cold finishing processes not followed by heat treatment for CH materials, including deformation induced by cold straightening (if applicable).

Validation of cold straightening shall include verification of mechanical properties. For rotary cold straightening, validation shall be for all quadrants at the middle of the product. For gag straightening, validation shall be at the longitudinal location of the product where deformation is greatest and shall include testing at the maximum tensile and compressive strain locations. The tested product should be representative of material that has been subject to the maximum induced fibre strain typical for the straightening operation, as determined by the manufacturer.

Manufacturers shall document the method used for validation and extent of the validation, including but not limited to the range of products, size range and manufacturing facilities.

6.6 Traceability

The manufacturer shall establish and follow procedures for maintaining heat, re-melt ingot and/or lot identity until all required heat, re-melt ingot and/or lot tests are performed and conformance with specification requirements has been shown.

6.7 Manufacturing procedure qualification test

If so specified in the purchase order, purchaser may request that an MPQT program be conducted for qualification of a range of product sizes for the specific purchaser or a change in the manufacturing process. Alternatively, the manufacturer may by agreement provide qualification data from a previous MPQT.

Annex H may be considered for the definition of the MPQT scope.

7 Material requirements

7.1 Chemical composition

In Table A.2 or Table C.2, generic types of alloy are listed with their nominal content of key chemical elements for PSL-1 products.

For PSL-1 products, the chemical composition and tolerances as agreed between purchaser and manufacturer shall be included in the purchase agreement.

In Table A.28 or Table C.28, the chemical analysis requirements for PSL-2 products are listed.

For group 2 material only, products in accordance with this document shall have a pitting-resistance equivalent number as stated in Table A.2 or Table C.2 for PSL-1 products or in Table A.28 or Table C.28 for PSL-2 products.

7.2 Tensile properties

Tensile properties at room temperature of pipes covered by this document shall meet the requirements given in Table A.3 or Table C.3 for PSL-1 products or in Table A.27 or Table C.27 for PSL-2 products.

In addition, the requirements in a) or b) shall also be met.

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a) The measured tensile strength shall be 69 MPa (10 ksi) greater than the specified minimum yield strength.

b) If the requirement in 7.2 a) is not met, then there shall be a 34 MPa (5 ksi) or greater difference between the measured tensile strength and the measured yield strength. By agreement between the purchaser and the manufacturer, the 34 MPa (5 ksi) requirement may be reduced.

When tensile properties at elevated temperature are requested by the purchaser, the values and the verification procedures shall be agreed between purchaser and manufacturer.

7.3 Hardness properties

The hardness of products covered by this document shall meet the requirements given in Table A.3 or Table C.3 for PSL-1 products or in Table A.27 or Table C.27 for PSL-2 products.

The through-wall hardness variation shall meet the requirements specified in Table A.4 or Table C.4.

No individual hardness number may be greater than 2 HRC units above the specified mean hardness number.

7.4 Charpy V-notch test properties — General requirements

7.4.1 Evaluation of test results

A test shall consist of a set of three specimens taken from one location from a single tubular product length. The average value of the three impact specimens shall equal or exceed the absorbed energy requirement specified in 7.5 and 7.6. In addition, not more than one impact specimen shall exhibit an absorbed energy below the absorbed energy requirement, and in no case shall an individual impact specimen exhibit an absorbed energy below two-thirds of the absorbed energy requirement.

For the purpose of determining conformance with these requirements, the observed result of a test shall be rounded to the nearest whole number. The impact energy value for a set of test specimens (i.e. average of three tests) shall be expressed as a whole number, rounded if necessary. Rounding shall be in accordance with the rounding method of ISO 80000-1 or ASTM E29.

7.4.2 Critical thickness

The absorbed energy requirements are based on the critical thickness. For pipe, the critical thickness is the specified wall thickness. For coupling stock and accessory material, the critical thickness should be specified on the purchase agreement. Otherwise, the critical thickness shall be the specified wall thickness.

For coupling stock and accessory material, the critical thickness should not be less than the calculated thickness of the internally threaded member at the plane of the small end of the pin (when the connection is made up power-tight).

7.4.3 Specimen size, orientation and hierarchy

When the use of full-size (10 mm × 10 mm) transverse test specimens is not possible, the largest possible sub-size transverse test specimen listed in Table A.5 or Table C.5 shall be used. When it is not possible to test using any of these transverse test specimens, the largest possible longitudinal test specimen listed in Table A.6 or Table C.6 shall be used for a group 1 product and flattening test

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specimens shall be used for a group 2, 3 or 4 product. The hierarchy of C_v test specimens orientation and size is specified in Table A.6 or Table C.6.

Table A.7 or Table C.7 for transverse specimens and Table A.8 or Table C.8 for longitudinal specimens provide the calculated wall thickness required to machine full-size or a smaller impact specimen (see Table A.5 or Table C.5). The impact-test specimen size that shall be selected from these tables is the largest impact test specimen having a calculated wall thickness that is equal or less than the specified wall thickness for the pipe, coupling stock or accessory material tested.

7.4.4 Alternative size impact test specimens

At the manufacturer's option, impact-test specimens of an alternative size, listed in Table A.5 or Table C.5, may be used in lieu of the minimum size specified determined from Table A.7 or Table C.7 or from Table A.8 or Table C.8. However, the alternative test specimen selected shall be higher on the hierarchy Table A.6 or Table C.6 than the specified size, and the absorbed energy requirement shall be adjusted in a manner consistent with the orientation and size of the impact specimen.

7.4.5 Sub-size test specimens

The minimum Charpy V-notch absorbed energy requirement for sub-size test specimens shall be that specified for a full-size test specimen multiplied by the reduction factor in Table A.5 or Table C.5.

7.4.6 Test temperature

The test temperature shall be –10 °C (14 °F). An alternative lower test temperature may be specified on the purchase agreement or selected by the manufacturer for any grade. The tolerance on the test temperature shall be ± 1 °C (± 2 °F).

7.5 Charpy V-notch — Absorbed energy requirements for coupling stock and accessory material — All grades

7.5.1 General

Coupling stock and accessory material suitable for more than one type of connection may be qualified by a test to demonstrate conformance to the most stringent requirements.

7.5.2 Requirements for all grades

The minimum absorbed energy requirement, C_v, for full-size test specimens is provided in Table A.9 or Table C.9, Table A.10 or Table C.10, and Table A.11 or Table C.11. The requirements are calculated based on the expressions given in Table 3, where

— $Y_{S,max}$ is the maximum specified yield strength, expressed in megapascals (thousand pounds per square inch);

— t is the critical wall thickness (see 7.4.2), expressed in millimetres (inches).

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Table 3 — Expressions for the minimum absorbed energy requirement for full-size test specimens of coupling stock and accessory material

Unit system and group		Transverse requirement C_v	Longitudinal requirement C_v
1		2	3
SI units of joules	Group 1	$Y_{S,max} \times (0{,}001\ 18\ t + 0{,}012\ 59)$ or 40 J, whichever is greater; see Table A.9	$Y_{S,max} \times (0{,}001\ 18\ t + 0{,}012\ 59)$ or 40 J, whichever is greater; see Table A.10
	Groups 2, 3 and 4	$Y_{S,max} \times (0{,}001\ 18\ t + 0{,}012\ 59)$ or 27 J, whichever is greater; see Table A.11	NA [a]
USC units of foot-pounds	Group 1	$Y_{S,max} \times (0{,}152\ t + 0{,}064)$ or 29 ft-lb, whichever is greater; see Table C.9	$Y_{S,max} \times (0{,}152\ t + 0{,}064)$ or 29 ft-lb, whichever is greater; see Table C.10
	Groups 2, 3 and 4	$Y_{S,max} \times (0{,}152\ t + 0{,}064)$ or 20 ft-lb, whichever is greater; see Table C.11	NA [a]
[a] When transverse Charpy V-notch tests ½ size or greater are not possible for groups 2, 3 and 4, then flattening tests are required.			

7.6 Charpy V-notch — Absorbed energy requirements for pipe — All grades

The minimum absorbed energy requirement, C_v, for full-size test specimens is provided in Table A.12 or Table C.12, Table A.13 or Table C.13, and Table A.14 or Table C.14. The requirements are calculated based on the expressions given in Table 4, where

— $Y_{S,min}$ is the minimum specified yield strength, expressed in megapascals (thousand pounds per square inch);

— t is the critical wall thickness (see 7.4.2), expressed in millimetres (inches).

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Table 4 — Expressions for the minimum absorbed energy requirement for full-size test specimens of pipe

Unit system and group		Transverse requirement C_v	Longitudinal requirement C_v
1		2	3
SI units of joules	Group 1	$Y_{S,min} \times (0{,}001\ 18\ t + 0{,}012\ 59)$ or 40 J, whichever is greater; see Table A.12	$Y_{S,min} \times (0{,}001\ 18\ t + 0{,}012\ 59)$ or 40 J, whichever is greater; see Table A.13
	Groups 2, 3 and 4	$Y_{S,min} \times (0{,}001\ 18\ t + 0{,}012\ 59)$ or 27 J, whichever is greater; see Table A.14	NA [a]
USC units of foot-pounds	Group 1	$Y_{S,min} \times (0{,}152\ t + 0{,}064)$ or 29 ft-lb, whichever is greater; see Table C.12	$Y_{S,min} \times (0{,}152\ t + 0{,}064)$ or 29 ft-lb, whichever is greater; see Table C.13
	Groups 2, 3 and 4	$Y_{S,min} \times (0{,}152\ t + 0{,}064)$ or 20 ft-lb, whichever is greater; see Table C.14	NA [a]

[a] When transverse Charpy V-notch tests ½ size or greater are not possible for groups 2, 3 and 4, then flattening tests are required.

7.7 Flattening requirements

For groups 2, 3 or 4, flattening tests shall be made as an alternative to impact tests when the outside diameter or wall thickness precludes the machining of transverse impact test specimens ½ size or larger. By agreement between the purchaser and manufacturer for groups 3 and 4, flattening tests may be performed in addition to the impact tests that are required when ½ size or larger transverse specimens can be machined.

When flattening tests are required, products with D/t ratios between 3 and 15 shall be flattened until the distance between the plates is less than or equal to S, expressed in percent, of the specified outside diameter, D, as calculated by Formula (1) for SI units and by Formula (2) for USC units:

$$S = 100 - \{[3{,}845\ 8 \ln(Y_{S,max}) - 24{,}344] \times D/t\} \quad (1)$$

$$S = 100 - \{[3.845\ 8 \ln(Y_{S,max}) - 16.919] \times D/t\} \quad (2)$$

where

$Y_{S,max}$ is the maximum specified yield strength, expressed in megapascals (thousand pounds per square inch);

D is the specified outside diameter of the product, expressed in millimetres (inches);

t is the specified wall thickness of the product, expressed in millimetres (inches);

ln is the natural logarithm of the maximum specified yield strength.

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When the D/t ratio is outside the above limits, the distance between the plates to be reached for flattening shall be by agreement between the purchaser and manufacturer.

Each ring shall be flattened to the maximum distance between the plates specified above.

Occurrence of a load drop-off, before meeting the specified deflection, shall be determined from the load versus deflection test record. A load drop-off that exceeds 5 % of the instantaneous load prior to the drop-off shall be cause for rejection. When the record does not show a load drop-off above 5 %, cracks shall not be cause for rejection.

7.8 Corrosion properties

Corrosion testing for quality control purposes is not mandatory and is not normally required. At the purchaser's option, quality control corrosion testing may be specified in the purchase agreement.

7.9 Microstructure properties

7.9.1 Group 1

For martensitic material, the delta ferrite content shall not exceed 5 %.

For category 13-1-0, the ferrite content may exceed 5 % by agreement between purchaser and manufacturer.

The microstructures shall have grain boundaries with no continuous precipitates or ferrite network.

7.9.2 Group 2

The microstructure shall have a ferritic-austenitic structure.

For duplex alloys, the ferrite volume fraction shall be in the range 40 % to 60 %.

For super-duplex alloys, the ferrite volume fraction shall be in the range 35 % to 55 %.

The microstructure shall be free from intermetallic precipitates, except for discrete/standalone intermetallic precipitates provided these are located in isolated areas and not homogeneously distributed throughout the test specimen, and that the maximum dimension of each precipitate does not exceed 10 µm (0.40 mil).

Micrographs included in Annex I are showing examples of microstructures.

Grain and phase boundaries shall be free from continuous networks of precipitates.

If carbide or nitride precipitates are observed, the findings shall be reported and documented, and the acceptance shall be based upon the Charpy V-notch or flattening test as per 7.6 and 7.7.

NOTE While determination of the nitride phase balance is impractical, the presence of nitrides in the ferrite phase reduces the Charpy V-notch property, increases micro hardness in the ferrite phase and reduces the breakthrough pitting corrosion potential. Quality control to avoid excessive nitrides is therefore best achieved by meeting the impact properties given in this specification.

7.9.3 Groups 3 and 4

The microstructure shall have an austenitic structure.

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The microstructure shall be free from intermetallic phases and carbides/nitrides precipitates, except for discrete/standalone precipitates. Grain boundaries shall be free from continuous networks of precipitates.

Micrographs included in Annex I are showing examples of microstructures.

Grain size shall be reported.

7.10 Surface condition

The internal surface of pipes shall be free from scale and annealing residues. If the purchaser has special requirements for the pipe surface, this shall be stated at the time of enquiry and order. The purchaser shall in this case specify the method, frequency, roughness values and extent of testing.

7.11 Defects

7.11.1 Pipe

All pipes shall be free from the following defects:

a) any quench crack or arc burn;

b) any surface-breaking imperfection that is proven to reduce the net effective wall thickness below 87,5 % of the specified wall thickness for hot-finished products or 90 % for other products;

c) any linear imperfection on the outside or inside surface, of any orientation, with a depth greater than 5 % of the specified wall thickness or 0,3 mm (0.012 in), whichever is greater, in the radial direction;

d) any non-surface-breaking imperfection detected that, when outlined on the outside surface, has an area greater than 260 mm^2 (0.40 in^2);

e) any surface-breaking pipe-upset imperfection, of any orientation, with a depth greater than 5 % of the specified pipe body wall thickness; the minimum wall thickness in the upset run-out interval, and the maximum combined effect of coincident internal and external imperfections in all areas, shall not result in the remaining wall below the imperfections being less than 87,5 % of the specified wall thickness;

f) on the internal upset configuration on all upset products, any sharp corner or drastic change of section that can cause a 90° hook-type tool to hang up (see Figure B.3).

7.11.2 Coupling stock and accessory material

All coupling stock and accessory material shall be free from any quench crack or arc burn. All coupling stock and accessory material shall be free from, or have clearly marked, any other outside-surface-breaking imperfection with a depth greater than 5 % of the specified wall thickness or that is proven to reduce the outside diameter or wall thickness below specified tolerances. Also, the requirement of 7.11.1 d) shall apply.

7.11.3 Process control plan

The manufacturer, based on knowledge of the production process and the requirements of Clause 9, shall apply a process control plan that ensures that the requirements of 7.11.1 and 7.11.2 are fulfilled.

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7.12 Hydrostatic test

All HF, SA, and QT pipe shall be hydrostatically tested, unless otherwise specified in the purchase agreement.

CH pipe shall be tested if agreed upon between purchaser and manufacturer.

Due to possible limitations on some testing equipment, the hydrostatic test pressure may be, upon agreement with the purchaser, limited to 69 MPa (10 ksi). In this case, the manufacturer shall have a documented design basis to establish the physical limitation of the hydrostatic test equipment. This does not preclude conducting subsequent hydrostatic tests at a fibre stress not exceeding 80 % of yield strength, as specified in 9.14.

8 Dimensions, masses and tolerances

8.1 Outside diameter, wall thickness and mass

8.1.1 The outside diameter, wall thickness and mass of the pipes for casing and tubing covered by this document are given in Table A.15 or Table C.15. The masses included in Table A.15 or Table C.15 are calculated using a factor of 1. In order to determine the masses relating to the different materials, the masses in Table A.15 or Table C.15 shall be multiplied using the following multiplication factors:

— 0,989 for ferritic and martensitic steels — Group 1;

— 1 for duplex and super-duplex steels — Group 2;

— α for austenitic steels — Group 3;

— β for austenitic Ni-based alloys — Group 4.

The α and β values shall be provided by the manufacturer.

8.1.2 Dimensions other than those in Table A.15 or Table C.15 may be agreed at the time of enquiry and order.

8.1.3 Diameter shall be measured rounding to one decimal place in millimetres and three decimal places in inches. In this document, two decimal places are used in Table A.15 for label 1 larger than 6 5⁄8 for design purposes to ensure interchangeability.

8.2 Length

The pipes shall be delivered with the range lengths listed in Table A.16 or Table C.16.

8.3 Tolerances

8.3.1 Tolerance on outside diameter, wall thickness and mass

The outside diameter, wall thickness and mass of the pipe for casing and tubing shall be within the tolerance limits given in Table A.17 or Table C.17.

For coupling stock and accessory material, the tolerance on outside diameter, wall thickness and mass shall be specified at the time of enquiry and agreed on in the purchaser agreement.

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8.3.2 Inside diameter, *d*

There is no direct tolerance set on inside diameter, *d*.

8.3.3 Straightness

Deviation from straightness, or chord height, shall not exceed either of the following:

— 0,2 % of the total length of the pipe, measured from one end of the pipe to the other end for pipe with a diameter > 101,60 mm (4 in) (see Figure B.1);

— 3,18 mm (0.125 in) maximum drop at each end, in the transverse direction for a length of 1,52 m (5 ft) (see Figure B.2).

8.3.4 Drift requirements

Each pipe shall be drift-tested throughout its entire length. Standard drift sizes for casing and tubing shall be as specified in Table A.18 or Table C.18.

An alternate drift mandrel size may be specified by the purchaser. For common alternate drift sizes, see Table A.19 or Table C.19.

8.4 Product ends

All plain end product shall be free from burrs and out-of-squareness shall be within 0,01 *D*.

9 Inspection and testing

9.1 Test equipment

The manufacturer shall determine and document the appropriate calibration frequency and reference standards in order to be able to certify that all products conform to the requirements of this document.

If test or measuring equipment, whose calibration or verification is required under the provisions of this document, is subjected to unusual or severe conditions that make its accuracy questionable, recalibration or reverification shall be performed before further use of the equipment.

9.2 Type and frequency of tests

The tests carried out and the test frequency are given in Table A.20 or Table C.20.

No test is required for pup joints manufactured from a length of casing or tubing, provided that it has been previously tested and conforms to requirements and there is no subsequent heat treatment.

9.3 Testing of chemical composition

9.3.1 Chemical analysis

The results of the chemical analysis made on each heat shall be provided by the manufacturer.

The report shall include the results of quantitative determination of elements as follows:

— for PSL-1, the elements listed in Table A.2 or Table C.2 plus Si, Mn, S, P and Al;

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— for PSL-2, the elements specified in Table A.28 or Table C.28;

— for PSL-1 and PSL-2, any other elements used by the manufacturer to control properties.

An analysis of the finished product shall be made on

a) two samples per heat for non-remelted alloy;

b) one sample per remelted ingot for remelted alloy.

By agreement between purchaser and manufacturer, samples may be taken from the semi-finished product.

Samples shall be taken in accordance with ISO 14284.

9.3.2 Test method

Selection of a suitable method for chemical analysis shall be at the discretion of the manufacturer. Often, the method of spectrometric analysis is used.

NOTE ISO/TR 9769, ASTM A751, ASTM E1473 and ASTM B880 provide a list of available standards specifying methods for chemical analysis, including information on their fields of application and accuracy.

9.3.3 Chromium depletion test — Groups 2, 3 and 4

When specified in the purchase agreement, one sample per test lot (3.1.22) shall be examined for surface chromium content using the EDX (energy dispersive X-ray spectrometry) or an equivalent method. The sample shall be taken on the product in its final delivery condition, but no special surface preparation shall be done before the test. The measured chromium content on the outside and inside surfaces shall not be less than 12,0 %. A higher minimum chromium content may be agreed between purchaser and manufacturer.

If a sample fails to meet the requirements, two additional samples from the same product shall be tested. If either of the additional samples fails, the manufacturer may elect either to test each of the remaining products in the test lot or to rework (e.g. additional pickling and/or grinding) and test the lot as a new lot.

9.4 Testing of mechanical characteristics

9.4.1 Test lot

The number of products per test lot (3.1.22) shall comply with the requirements of Table A.21 or Table C.21.

9.4.2 Selection and preparation of samples and test pieces

Samples and test pieces shall be taken at the pipe ends and shall be in accordance with the requirements of ISO 377.

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9.5 Tensile test

9.5.1 Orientation and size of test pieces

The test pieces shall be taken longitudinally to the pipe axis in accordance with the requirements of ISO 6892-1 or ASTM A370.

In case round-bar specimens are used, the largest gauge diameter compatible with the wall thickness of the product shall be used.

9.5.2 Test method

A tensile test shall be carried out at room temperature in accordance with ISO 6892-1 or ASTM A370.

The tensile strength, R_m, the yield strength, $R_{p0,2}$, and the percentage elongation after fracture, e, shall be determined during the tensile test.

The results of the tensile test shall comply with the requirement of 7.2 and with the values for the material category and grade specified in Table A.3 or Table C.3 for PSL-1 products or in Table A.27 or Table C.27 for PSL-2 products.

If agreed at the time of ordering, a tensile test at elevated temperature shall be carried out in accordance with ISO 6892-2 or ASTM E21. The yield strength, $R_{p0,2}$, shall be determined during the tensile test at the temperature agreed at the time of enquiry and order. The result of the tensile test shall comply with the value agreed at the time of enquiry and order.

9.5.3 Invalidation of test

Any test specimen that shows defective preparation or material imperfections unrelated to the intent of the test, whether observed before or after testing, may be discarded and be replaced by another specimen from the same product. Specimens shall not be judged defective for the sole reason that they fail to meet the required properties.

9.5.4 Retest

If a tensile test representing a lot fails to conform to the specified requirements, the manufacturer may elect to carry out retests on three additional products from the same lot. In the case of test lots with three or fewer products, each product shall be tested. If all of the retests conform to the requirements, the lot shall be accepted, excepting the failed product.

If one or more of the retest specimens fails to conform to the specified requirements, the manufacturer may elect to test each of the remaining products in the lot. Any product that fails shall be rejected. Specimens for retests shall be taken in the same manner as specified in 9.4.2.

Rejected lots may be re-heat-treated and tested as new lots, as applicable.

9.6 Hardness test

9.6.1 Test pieces

The test piece for the hardness test shall be a ring or product test block cut from one end of the sample pipe. The test ring or product test block shall be a minimum of 12,7 mm (½ in) long.

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The surfaces of the test piece that contact the anvil and the indenter shall be machined parallel within 0,5° and smooth with an average surface roughness of 0,6 µm (25 µin) or finer, as defined by *Ra* value in ISO 4287. They shall be visually inspected and shall be free of visible foreign matter, lubricants and burrs.

When product test blocks or rings are prepared using consistent machining processes that ensure this requirement is met, verification of parallelism and roughness are not required. Otherwise, the parallelism and the roughness shall be verified on each test piece.

9.6.2 Test method

A single indentation test block in one quadrant shall be tested as illustrated in detail 4 of Figure B.4. A row of three hardness indentations shall be made at required locations (outer, midwall, inner as applicable) and the hardness numbers shall be averaged to give one mean hardness number for each location.

The minimum number of rows shall be determined by the wall thickness of the product, see detail *a* in Figure B.4. For wall thickness lower or equal to 7,62 mm (0.300 in), one row shall be used. For wall thickness higher than 7,62 mm (0.300 in) and lower or equal to 11,43 mm (0.450 in), two rows shall be used. For wall thickness higher than 11,43 mm (0.450 in) three rows shall be used. The outer and inner locations shall be taken between 2,54 mm (0.100 in) and 3,81 mm (0.150 in) from the applicable surface.

An indentation shall not be spaced closer than two and a half diameters from its centre to the edge of the specimen or three diameters from another indentation measured centre to centre.

The mean hardness number is the average of three Rockwell hardness numbers in the same location as it is shown in detail *b* of Figure B.4. Rockwell hardness indentation data are called Rockwell hardness numbers; see detail *c* of Figure B.4.

A Rockwell hardness test shall be carried out in accordance with ISO 6508-1 or ASTM E18. Hardness tests shall be made using the Rockwell C scale. The mean Rockwell hardness numbers shall comply with the requirements of 7.3, Table A.4 or Table C.4, and with the hardness requirements for the material category and grade specified in Table A.3 or Table C.3 for PSL-1 products or in Table A.27 or Table C.27 for PSL-2 products.

The first indentation on a hardness test specimen shall be made near the centre of the test block specimen to help seat the test specimen and reduce the possibility of errors. The result of this first indentation shall be ignored and it is not necessary to record it.

Overhang of product test blocks or rings beyond the anvil support of less than or equal to 40 % of the surface area of the product test block or ring is acceptable. The overhang may exceed 40 % of the surface area of the product test block or ring when the testing equipment is designed and validated to yield consistently accurate results for such use. External support is not permitted.

The anvil and anvil seat shall not have protrusions or indentations that adversely affect the hardness result.

When standardized test blocks are used for the verification of a hardness machine, the same anvil shall be used for the verification as will be used for acceptance testing following the verification.

Only indenters that have been calibrated (verified) for use with the specific test machine to be used, such as during an indirect verification, shall be used. When other indenters are used, they shall be verified using an indirect verification with respect to a more accurate indenter (e.g. reference indenter with less error).

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The polished portion of the HRC indenter shall be visually inspected periodically for damage (e.g. cracks, chips, pits, etc.) with the aid of adequate magnification (e.g. 20X or higher).

If the difference between the highest and lowest indentations at a location (same outside-wall, mid-wall or inside-wall in a quadrant) is greater than 2,5 HRC, then three additional indentations in the same location shall be taken. In such case, the mean hardness number shall be based on the three additional indentations. The test report shall indicate that additional indentations were made and the original test data shall be available upon request.

9.6.3 Invalidation of tests

Any test specimen that shows defective preparation or material imperfections unrelated to the intent of the test, whether observed before or after testing, may be discarded and be replaced by another specimen from the same product. Specimens shall not be judged defective for the sole reason that they fail to meet the required properties.

9.6.4 Periodic checks of hardness-testing machines

Periodic checks of testing machines shall be made using the procedures in ISO 6508-1 or ASTM E18 for Rockwell hardness test machines.

NOTE Relevant ISO text is entitled “Procedure for periodic checks of the testing machines by the user” and ASTM paragraph is titled "Daily Verification".

The standardized test block shall have a maximum non-uniformity of 1,0 HRC. The non-uniformity of the standardized test block shall be determined by the difference between the highest and lowest indentation number stated in the standardized test block certificate.

At least two preliminary indentations on each standardized test block should be disregarded in order to reduce the possibility of errors. After the preliminary indentations, at least three hardness indentations shall be made on the standardized test block. The error shall not exceed ± 1,0 HRC. The error shall be determined by the certified mean hardness number of the standardized test block minus the mean hardness number determined during the periodic check.

The testing machine shall be checked at the beginning and end of a continuous run of testing and at such times as are required to assure the operator of the equipment and the purchaser (or his representative) that the machine is satisfactory. In any event, checks should be made at least every 8 h of a continuous run of testing. The hardness range of the test block shall be chosen to be within 10 Rockwell points of the hardness value that the testing machine is expected to measure.

If the checks indicate that the testing machine results are unsatisfactory, the machine shall be verified by indirect verification using standardized test blocks according to the procedures in ISO 6508-2 or ASTM E18 for Rockwell hardness test machines.

The results obtained from the periodic checks shall be recorded and should be analysed using accepted Statistical Process Control techniques, such as, but not limited to, X-bar (measurement averages) and R-charts (measurement ranges) and histograms.

9.6.5 Verification of hardness-testing machines and indenters

Indirect verification of hardness testing machines shall be performed at least once every 13 months and after a direct verification has been performed, in accordance with the procedures in ISO 6508-2 or ASTM E18 for Rockwell hardness test machines.

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The HRC standardized test blocks shall be within 20 HRC to 50 HRC to confirm accuracy and linearity using a two-block verification. The standardized test blocks used shall bracket the HRC range for acceptance testing. The standardized test blocks shall have a maximum non-uniformity of 0,4 HRC (difference between the highest and lowest indentation number stated in the standardized test block certificate). The error shall not exceed ± 0,5 HRC (determined by the certified mean hardness number of the standardized test block minus the mean hardness number determined during the indirect verification).

The indenter should be directly verified at least every 2 years. HRC indenters shall be certified by the manufacturer for performance error (deviation) with respect to a more accurate indenter (e.g. reference indenter with less error) and standardized test blocks in the range being tested. HRC indenters shall have a maximum performance error of ± 0,4 HRC.

A calibration certificate (verification report) for the hardness tester shall be issued by an independent certifying agency. The calibration agency that is used to conduct verifications of hardness testing machines and HRC indenters should be accredited to the requirements of ISO/IEC 17025 or equivalent by a recognized accreditation body that operates in according to the requirements of ISO/IEC 17011. As a minimum, the calibration certificate shall identify:

a) the reference standard (ISO 6508-2 and/or ASTM E18);

b) method of verification (direct and/or indirect);

c) means of verification (reference blocks, elastic proving devices, etc.);

d) temperature;

e) hardness scale(s) verified;

f) date of the verification;

g) standardized test blocks references (mean hardness number, scale, serial number, manufacturer and non-uniformity);

h) results obtained;

i) identification of the hardness test machine (manufacturer, model number and serial number);

j) serial number of indenter;

k) certifying agency;

l) name of their representative performing the verification.

9.6.6 Retests

If any mean hardness number fails to conform to specified requirements but does not exceed the specified requirements by more than 2,0 HRC units, three additional indentations shall be made in the immediate area to determine a new mean hardness number.

If the new mean hardness number conforms to the requirements, the piece shall be accepted.

If the new mean hardness number fails to conform to the requirements, the piece shall be rejected.

If a product is rejected due to exceeding maximum mean hardness or exceeding the maximum hardness variation, the manufacturer may elect to carry out retests on three additional products from the same lot from the same end as the original test specimen. If all the retests conform to the requirements, the

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